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RESEARCH MEMORANDUM

STATISTICAL MEASUREMENTS OF LANDING CONTACT CONDITIONS OF THE BOEING B-47 AIRPLANE

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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STATISTICAL MEASUREMENTS OF LANDING CONTACT CONDITIONS OF THE BOEING B-47 AIRPLANE

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SUMMARY

The landing contact conditions of the Boeing B-47 airplane were determined from photographs, taken with a specially built motion-picture camera, of 222 landings during daytime operations at Barksdale Air Force Base, La. The statistical analysis of the sinking speeds and the horizontal speeds evaluated from these photographs indicated that in 1 out of 1,000 landings the sinking speed will equal or exceed about 6 feet per second and the airspeed at contact will equal or exceed about 70 percent above stall. The mean sinking speed was 2.0 feet per second and the mean airspeed at contact was 23 percent above stalling speed. The frequency distribution and probability curve for sinking speeds for the present data and that obtained by the Boeing Airplane Company showed reasonable agreement.

INTRODUCTION

One of the phases of the landing-loads problem that the National Advisory Committee for Aeronautics is currently investigating is the measurement of the initial landing contact conditions of various types of airplanes to provide a statistical basis for evaluating present design criteria. Some results previously obtained as part of this study were reported in references 1 and 2.

The purpose of this paper is to present the sinking speed and the forward speed at the time of the first wheel contact for 222 landings of the Boeing B-47 medium jet bomber airplane at Barksdale Air Force Base in April 1954. The data are summarized in the form of frequency distributions, cumulative frequency distributions, and probability curves. A comparison is made with some measurements of B-47 landings made by the Boeing Airplane Company at Wichita Air Force Base as reported in reference 3.

APPARATUS AND METHOD

A 35-mm motion-picture camera supported on a vertical shaft which was rigidly mounted to a steel trailer was used to obtain data on landing contact conditions. The motion-picture camera ran at 25 frames per second and was fitted with a 40-inch focal-length telescopic lens. Tracking of the airplane was limited to azimuth by the vertical shaft on which the camera was mounted. The trailer was raised on jacks which provided a rigid support and permitted accurate leveling of the camera. Reference 4 gives a complete description of the camera equipment, its design considerations, the method of reducing data, and the accuracy of the measurement.

Some pertinent general specifications for the B-47 airplane are given in table I. The landings photographed included practice landings in which the airplane touched the ground and then took off again and also landings in which the airplane landed and stayed down. Details of the method and equations for the reduction of the data are given in reference 4 for the sinking speed and in reference 1 for airspeed at contact.

STATISTICAL ANALYSIS AND DISCUSSION

The frequency distributions of sinking speed for the first wheel to touch and of the airspeed at contact representing their respective class intervals are tabulated in table II. The results of the statistical analysis are presented in figures 1 to 4. The frequency distributions are given in figures 1 and 3 and the probability curves in figures 2 and 4. The probability data were arbitrarily faired by Pearson type III curves and the various parameters such as the mean, standard deviation, and coefficient of skewness used to determine these curves, in the manner presented in reference 5, are shown in table II. The points plotted on the probability curves in figures 2 and 4 represent the cumulative frequencies for the same intervals as their respective frequency distributions. No attempt was made to analyze the data on the basis of whether the landings were of the touch-and-go or stay-down type because the number of stay-down landings (44) was considered too small a sample to be significant. Further, no analysis was made for gust and no-gust conditions (as in ref. 1) because only 16 of the landings were made under gusty conditions.

For comparison, the sinking speeds obtained by photographic means for the B-47 landings at Wichita Air Force Base and reported in reference 3 are also shown. The frequency distribution of sinking speed was used directly from reference 3. The cumulative totals and the probability curve were computed from this frequency distribution.

The landing weights used to obtain the stalling speeds were estimated from an analysis of time used for each landing, the known fuel-consumption rate, and the known number of landings for each airplane. It was assumed that all landings were made between the restricted maximum gross landing weight and the minimum desired gross landing weight shown in table I. This table also gives the lift coefficients for stall, best flare speed, and speed for simultaneous contact of main wheels. Due to a data-reduction difficulty, the airspeed at contact could be obtained for only 211 out of 222 landings used for obtaining sinking speed.

Sinking Speed

The frequency distribution of sinking speed for the present data (fig. 1) indicates that the greatest percentage, 24.8 percent, of the landings occurred at sinking speeds between 1.5 and 2.0 feet per second. The mean sinking speed for the 222 landings was 1.97 feet per second, and the highest was 6.3 feet per second. A comparison of the frequency distribution with that for 215 landings from reference 3 shows reasonable agreement. Although there were some differences in the two frequency distributions between sinking speeds of 1.5 to 2.5 feet per second, approximately 50 percent of the landings for both occurred in this range. The mean sinking speed given in reference 3 was 2.0 feet per second.

The probability curve for sinking speed (fig. 2) indicates that the sinking speed will equal or exceed about 2.0 feet per second once in 2 landings; about 3.0 feet per second for 1 in 10 landings; about 4.5 feet per second for 1 in 100 landings; and about 6.0 feet per second for 1 in 1,000 landings. A comparison of the probability curve with that computed from the frequency distribution from reference 3 shows little difference between the two curves.

Airspeed at Contact

The frequency distribution of airspeed above stall (fig. 3) shows that the greatest percentage of landings, 27.5 percent, occurred in the range from 20 to 25 percent above stall. The mean value for the 211 landings was 23.0 percent above stall. Two landings were made at 68.5 and 64.5 percent above stall although the next lowest was 49.6 percent above stall. The lowest percent above stall was 3.8.

It is of interest to note that the mean of 23.0 percent above stall is about the midpoint in the recommended B-47 landing-speed range. This range is between the best flare speed and the speed for simultaneous contact of the tandem main wheels. Of the 211 landings, 42.4 percent or 89 landings were made in the recommended speed range.

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The probability curve (fig. 4) for the percentage by which contact airspeed will exceed the stalling speed indicates that airspeed will equal or exceed about 35 percent above stall in 1 out of 10 landings; about 50 percent above stall in 1 out of 100 landings; and about 70 percent above stall in 1 out of 1,000 landings.

CONCLUDING REMARKS

Results of the statistical analysis of the contact conditions for more than 200 landings of the Boeing B-47 airplane during daytime operations indicate that in 1 out of 1,000 landings, the sinking speed will equal or exceed about 6 feet per second and the airspeed at contact will equal or exceed about 70 percent above stall.

The mean sinking speed was 2.0 feet per second and the mean airspeed at contact was 23 percent above stall. The frequency distribution and probability curve for sinking speeds for the present data and that obtained by the Boeing Airplane Company showed reasonable agreement.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 17, 1955.

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REFERENCES

1. Silsby, Norman S.: Statistical Measurements of Contact Conditions of 478 Transport-Airplane Landings During Routine Daytime Operations. NACA TN 3194, 1954.

2. Silsby, Norman S., and Harrin, Eziaslav N.: Statistical Measurements of Landing-Contact Conditions of a Heavy Bomber. NACA RM L55E03, 1955.

3. Alldredge, J.: B-47 Landing Rates of Descent. Doc. No. WD-10693 (Contract No. AF33(600)-5148), Boeing Airplane Co., 1954.

4. Rind, Emanuel: A Photographic Method for Determining Vertical Velocities of Aircraft Immediately Prior to Landing. NACA TN 3050, 1954.

5. Kenney, John F.: Mathematics of Statistics. Part II. D. Van Nostrand Co., Inc., 1939, pp. 45-51.

TABLE I

GENERAL SPECIFICATIONS FOR THE BOEING B-47 AIRPLANE

Maximum gross take-off weight, lb	185,000
Restricted maximum gross landing weight, lb	115,000
Minimum desired gross landing weight, lb	90,000
Basic gross weight, lb	82,000
Wing area, sq ft	1,428
Lift coefficient, C_L -	
For stall at sea level	1.98
For simultaneous contact of main wheels at sea level	1.44
For best flare speed at sea level	1.27

[redacted]

TABLE II

TABULATION OF FREQUENCY DISTRIBUTION VALUES AND STATISTICAL PARAMETERS FOR LANDING CONTACT CONDITIONS

Sinking speed, ft/sec	Frequency distribution		Airspeed at contact, percent above stall	Frequency distribution	
	Percent of landings	Number of landings		Percent of landings	Number of landings
0 to 0.5	2.7	6	0 to 5	0.5	1
.5 to 1.0	11.3	25	5 to 10	2.4	5
1.0 to 1.5	14.0	31	10 to 15	11.8	25
1.5 to 2.0	24.8	55	15 to 20	25.1	53
2.0 to 2.5	21.6	48	20 to 25	27.5	58
2.5 to 3.0	14.4	32	25 to 30	14.7	31
3.0 to 3.5	6.3	14	30 to 35	9.5	20
3.5 to 4.0	2.3	5	35 to 40	4.7	10
4.0 to 4.5	1.8	4	40 to 45	1.9	4
5.0 to 5.5	.5	1	45 to 50	.9	2
6.0 to 6.5	.5	1	60 to 65	.5	1
			65 to 70	.5	1
Total number of landings		222	Total number of landings		211
Mean, ft/sec		1.97	Mean, percent above stall		23.0
Standard deviation, σ, ft/sec		0.81	Standard deviation, σ, percent above stall		8.74
Coefficient of skewness, α_3		1.20	Coefficient of skewness, α_3		1.52

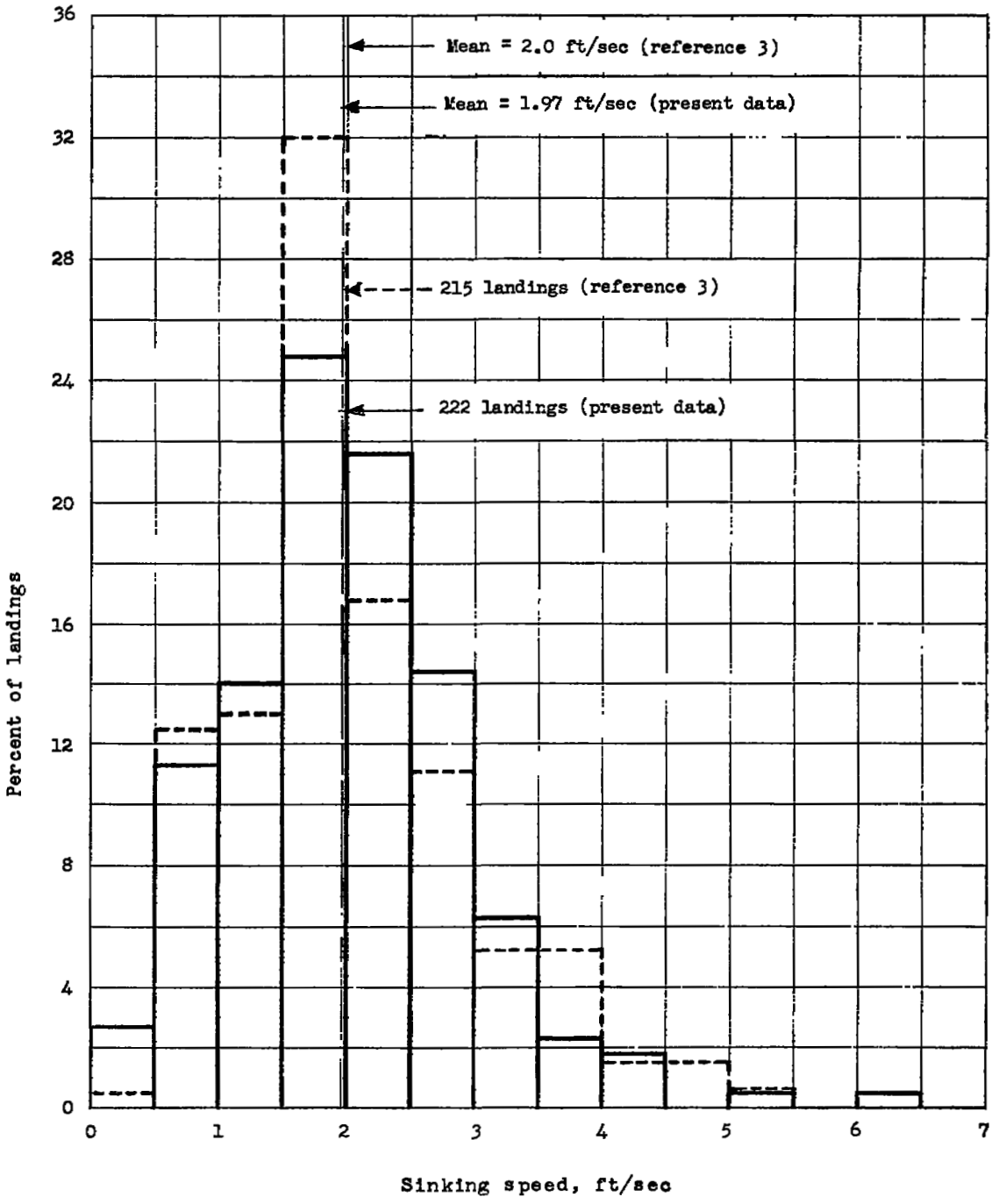

Figure 1.- Frequency distribution of sinking speed for B-47 airplane. Data from reference 3 are shown for comparison.

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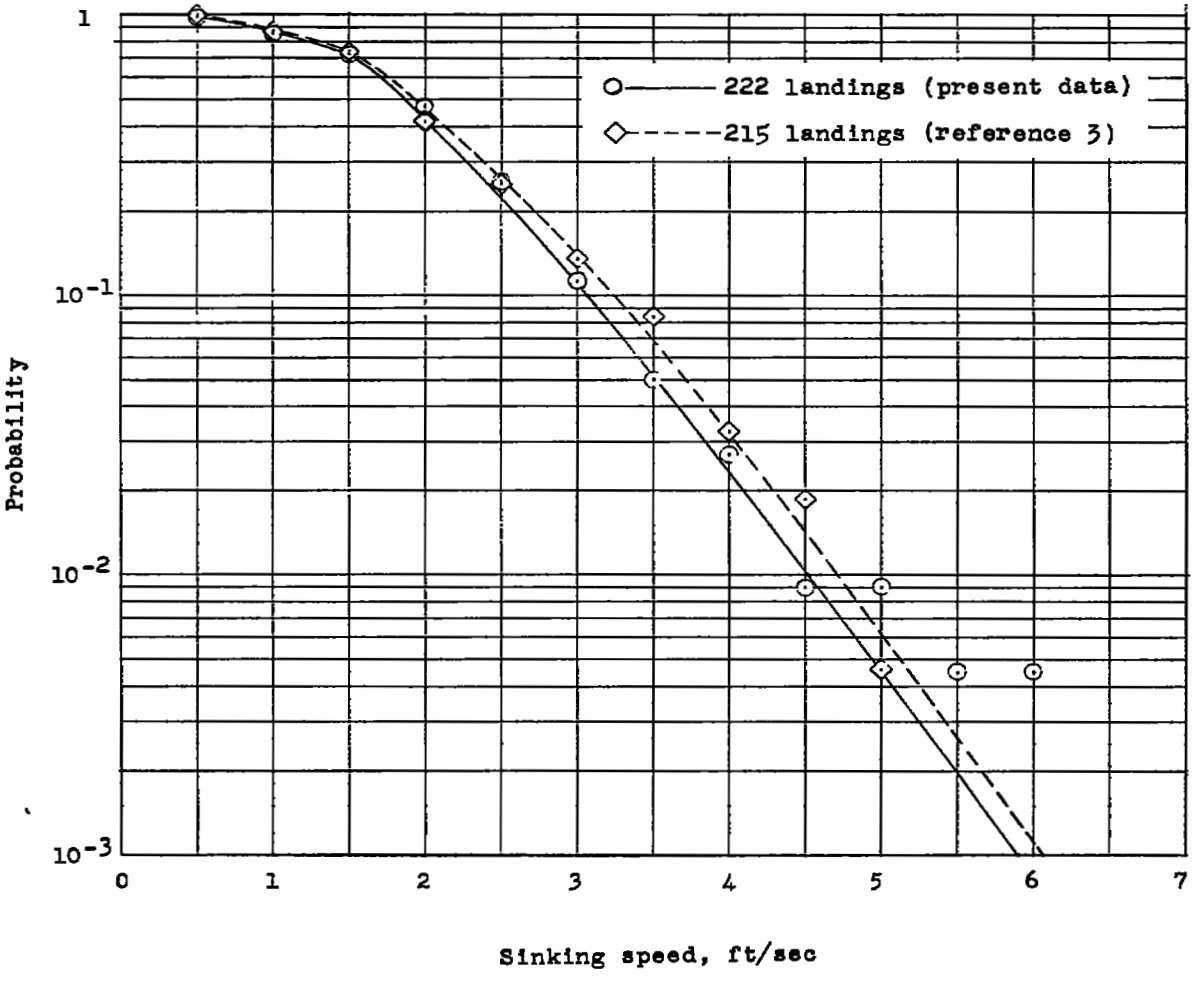

Figure 2.- Probability of equaling or exceeding sinking speed for B-47 airplane.

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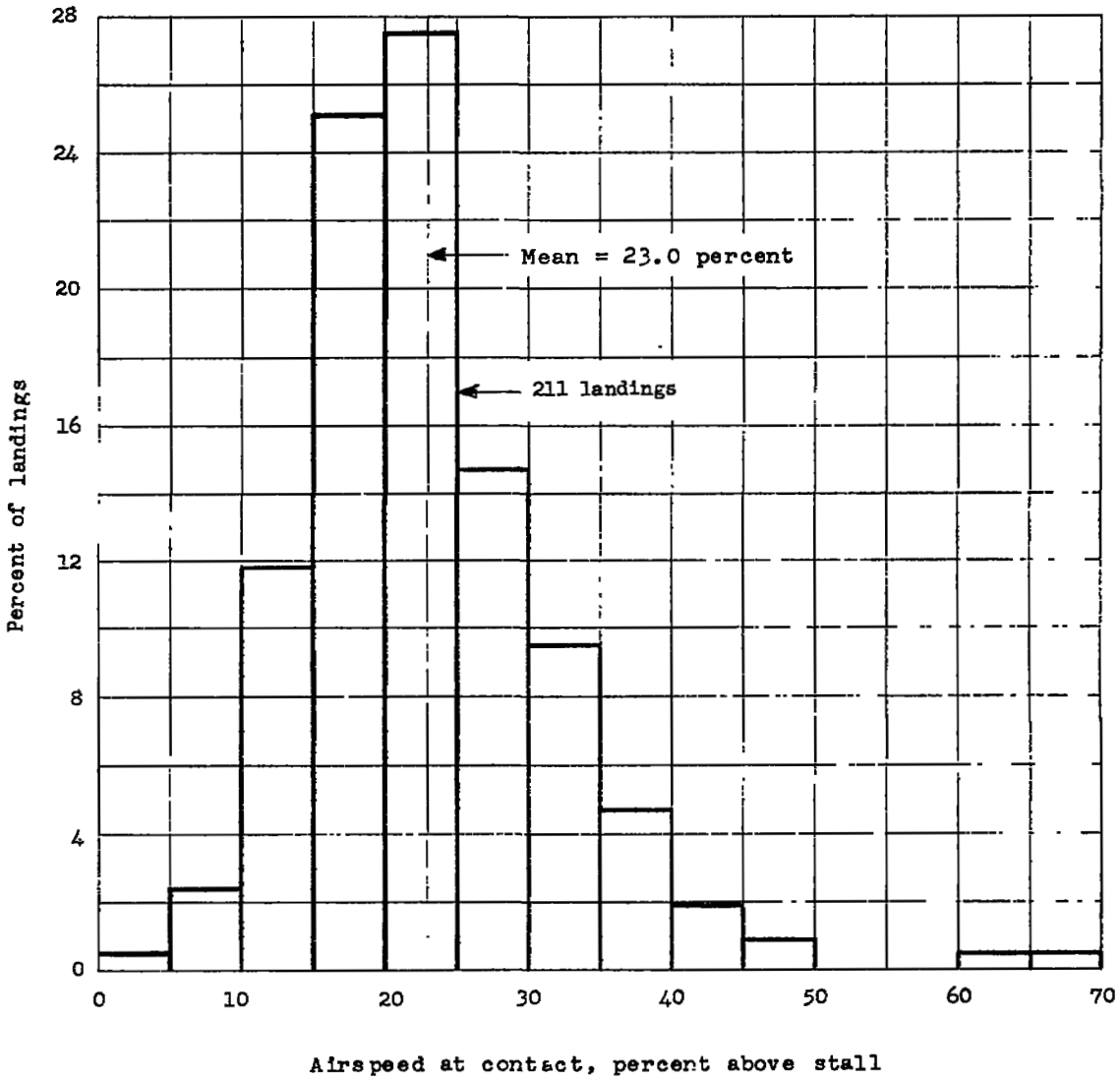

Figure 3.- Frequency distribution of airspeed in percent above stall of B-47 airplane.

[redacted]

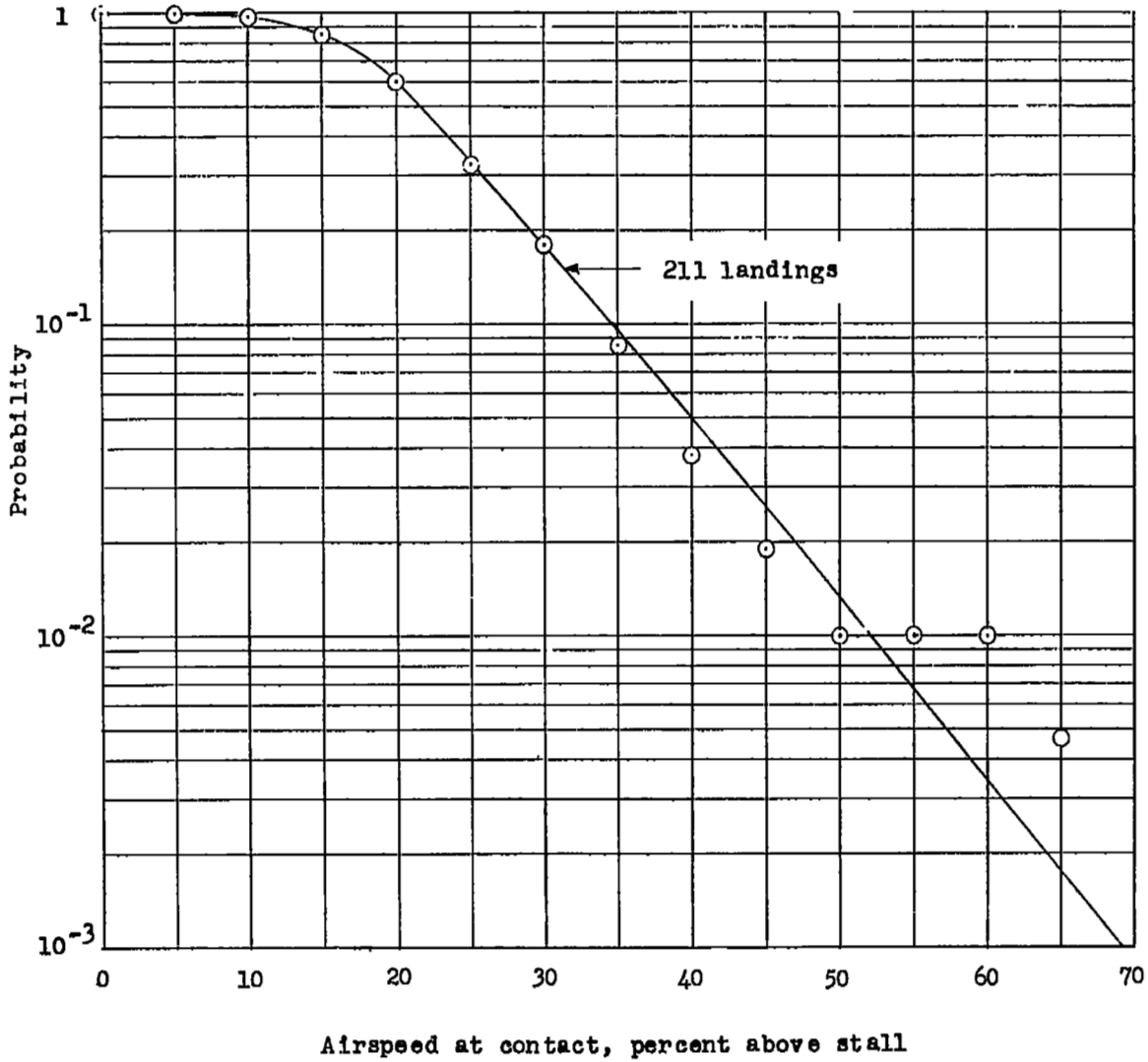

Figure 4.- Probability of equaling or exceeding airspeed at contact in percent above stall for B-47 airplane.